OPTICAL TRANSMISSION SYSTEM AND OPTICAL AMPLIFICATION METHOD USING IN THE SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to an optical transmission system and an optical amplification method using in the optical transmission system, in particular, in which the Raman amplification technology for amplifying signal light is used.

Description of the Related Art

At an optical transmission technology, the Raman amplification technology, in which the Raman scattering is generated in an optical transmission line by using the optical transmission line as its own amplification medium and signal light is directly amplified, has been well known. At this Raman amplification technology, the Raman amplification phenomenon, in which a gain having a peak is generated at about 100 nm long wavelength side from the wavelength of a pumping light source, is used. In this Raman amplification technology, a gain wavelength is decided by the wavelength of the pumping light source. Therefore, at the optical signal transmission system using the wavelength division multiplexing (WDM) system, a designing method, which keeps the signal light in a flat state by combining pumping light sources of plural wavelengths, has been generally used. This technology has been reported at the 2001 Communications Society Conference B-10-66 of The Institute of Electronics, Information and Communication Engineers. Consequently, when a pumping light source had a failure, it is necessary to have a means to compensate the change of the gain wavelength characteristic.

And at the Raman amplification technology, the gain is decided by the pumping intensity, and the self healing phenomenon,

which the gain is recovered after several repeats at amplifiers using an erbium doped fiber (EDF), is not generated. In order to solve this problem, there are several methods. In a method, a pumping light source for redundancy is provided in each of the light sources for Raman amplification. And in another method, the pumping light intensity is compensated by allocating the pumping light intensity to the several light sources for Raman amplification disposed after a light source for Raman amplification whose pumping light source had a failure. These methods have been reported in the 2001 Communications Society Conference B-10-62 of The Institute of Electronics, Information and Communication Engineers.

However, in case that the pumping light source for redundancy is provided in all of the light sources for Raman amplification, there is a problem that the cost of the optical transmission system is increased. And in case that a pumping light source had a failure, when the pumping light intensity is compensated by the plural light sources for Raman amplification disposed after the light source that had a failure, there is a problem that each of the pumping light sources must have excess pumping light intensity ability that is not used in a normal state.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an optical transmission system and an optical amplification method using in the system, in which the number of pumping light sources for redundancy is decreased and the maximum output level ability of each of pumping light sources is made to be low.

According to a first aspect of the present invention, for achieving the object mentioned above, there is provided an optical transmission system. The optical transmission system provides one

or more first light sources for Raman amplification that amplify signal light transmitting in an optical transmission line, and one or more second light sources for Raman amplification that are disposed at the positions adjoining the one or more first light sources for Raman amplification via the optical transmission line. And each of the one or more first light sources for Raman amplification provides a first pumping light source that emits first pumping light at a normal time as a pumping light source, and a first optical multiplexer that inputs the first pumping light to the optical transmission line. And each of the one or more second light sources for Raman amplification provides a second pumping light source that emits second pumping light of the same wavelength band of the first pumping light at a normal time as a pumping light source, a spare pumping light source that emits spare pumping light of the same wavelength band of the first pumping light based on necessity, an optical coupler that couples the second pumping light and the spare pumping light, and a second optical multiplexer that inputs the coupled pumping light to the optical transmission line. And in case that a failure occurred at the first or second pumping light source, the spare pumping light source is worked and the spare pumping light is emitted.

According to a second aspect of the present invention, there is provided an optical transmission system. The optical transmission system provides one or more first light sources for Raman amplification that amplify signal light transmitting in an optical transmission line, and one or more second light sources for Raman amplification that are disposed at the positions adjoining the one or more first light sources for Raman amplification via the optical transmission line. And each of the one or more first light sources for Raman amplification provides plural first pumping light sources that emit plural first pumping light whose wavelengths are different from

each other at a normal time, as pumping light sources, a first optical multiplexer that multiplexes the plural first pumping light, and a second optical multiplexer that inputs the multiplxed first pumping light to the optical transmission line. And each of the one or more second light sources for Raman amplification provides plural second pumping light sources that emit plural second pumping light whose wavelengths are the same ones corresponding to the plural first pumping light sources at a normal time, as pumping light sources, plural spare pumping light sources that emit plural spare pumping light whose wavelengths are the same ones corresponding to the plural second pumping light sources based on necessity, plural optical couplers that couple the second pumping light and the spare pumping light of the same wavelength band, a third optical multiplexer that multiplexes plural coupled pumping light whose wavelengths are different from each other, and a fourth optical multiplexer that inputs multiplexed pumping light to the optical transmission line. And in case that a failure occurred at one in the plural first or plural second pumping light sources, the spare pumping light source whose wavelength band is the same one that the failure occurred is worked and the spare pumping light is emitted.

According to a third aspect of the present invention, in the first aspect, in case that a failure occurred at the first or second pumping light source, the spare pumping light is emitted from the spare pumping light source so that the output level of the signal light becomes the same output level before the failure occurred.

According to a fourth aspect of the present invention, in the second aspect, in case that a failure occurred at one in the plural first or plural second pumping light sources, the spare pumping light is emitted from corresponding one of the plural spare pumping light sources so that the output level of the signal light becomes the same

output level before the failure occurred.

According to a fifth aspect of the present invention, in the first aspect, in case that a failure occurred at the first or second pumping light source, the spare pumping light is emitted from the spare pumping light source so that the gain wavelength characteristic of the signal light becomes the same gain wavelength characteristic before the failure occurred.

According to a sixth aspect of the present invention, in the second aspect, in case that a failure occurred at one in the plural first or plural second pumping light sources, the spare pumping light is emitted from corresponding one of the plural spare pumping light sources so that the gain wavelength characteristic of the signal light becomes the same gain wavelength characteristic before the failure occurred.

According to a seventh aspect of the present invention, in the first aspect, each of the one or more first light sources for Raman amplification further provides a control circuit that controls the first pumping light source. And each of the one or more second light sources for Raman amplification further provides a control circuit that controls the second pumping light source and the spare pumping light source.

According to an eighth aspect of the present invention, in the second aspect, each of the one or more first light sources for Raman amplification further provides a control circuit that controls the plural first pumping light sources. And each of the one or more second light sources for Raman amplification further provides a control circuit that controls the plural second pumping light sources and the plural spare pumping light sources.

According to a ninth aspect of the present invention, there is provided an optical transmission system. The optical transmission

system provides one or more light sources for Raman amplification not having a redundancy system that amplify signal light transmitting in plural optical transmission lines, and one or more light sources for Raman amplification having a redundancy system that are disposed at the positions adjoining the one or more light sources for Raman amplification not having the redundancy system via the plural optical transmission lines. And each of the one or more light sources for Raman amplification not having the redundancy system provides plural first pumping light sources that emit first pumping light whose wavelengths are different from each other at a normal time, as pumping light sources, a first means that multiplexes the plural first pumping light and splits mulitplexed pumping light into plural pumping light, and plural first optical multiplexers that input split pumping light to the plural optical transmission lines. And each of the one or more light sources for Raman amplification having the redundancy system provides plural second pumping light sources that emit second pumping light whose wavelengths are the same ones of the plural first pumping light sources at a normal time, as pumping light sources, plural spare pumping light sources that emit spare pumping light whose wavelength bands are the same ones corresponding to the plural first pumping light sources, based on necessity, plural optical couplers that couple the second pumping light and the spare pumping light of the same wavelength band, a second means that multiplexes plural coupled pumping light whose wavelengths are different from each other and splits mulitplexed pumping light into plural pumping light, and plural second optical multiplexers that input split pumping light to the plural optical transmission lines. And in case that a failure occurred at one in the plural first pumping light sources in the one or more light sources for Raman amplification not having the redundancy system or at one in

the plural second pumping light sources in the light sources for Raman amplification having the redundancy system, the spare pumping light source whose wavelength band is the same one that the failure occurred is worked and the spare pumping light is emitted.

According to a tenth aspect of the present invention, there is provided an optical transmission system. The optical transmission system provides one or more light sources for Raman amplification not having a redundancy system that amplify signal light transmitting in plural optical transmission lines, and one or more light sources for Raman amplification having a redundancy system that are disposed at the positions adjoining the one or more light sources for Raman amplification not having the redundancy system via the plural optical transmission lines. And each of the one or more light sources for Raman amplification not having the redundancy system provides plural first pumping light sources that emit first pumping light whose wavelengths are different from each other at a normal time, as pumping light sources, a first means that multiplexes the plural first pumping light and splits mulitplexed pumping light into plural pumping light, and plural first optical multiplexers that input split pumping light to the plural optical transmission lines. And each of the one or more light sources for Raman amplification having the redundancy system provides plural second pumping light sources that emit second pumping light whose wavelengths are the same ones of the plural first pumping light sources at a normal time, as pumping light sources, plural spare pumping light sources that emit spare pumping light whose wavelength bands are the same ones corresponding to the plural first pumping light sources, based on necessity, plural optical multiplexers that multiplex the second pumping light having different wavelengths in one of the plural optical multiplexers and multiplex the spare pumping light having different

wavelengths in other of the plural optical multiplexers, a second means that multiplexes plural multiplexed pumping light whose wavelengths are different from each other and splits mulitplexed pumping light into plural pumping light, and plural second optical multiplexers that input split pumping light to the plural optical transmission lines. And in case that a failure occurred at one in the plural first pumping light sources in the one or more light sources for Raman amplification not having the redundancy system or at one in the plural second pumping light sources in the light sources for Raman amplification having the redundancy system, the spare pumping light source whose wavelength band is the same one that the failure occurred is worked and the spare pumping light is emitted.

According to an eleventh aspect of the present invention, for achieving the object mentioned above, there is provided an optical amplification method in an optical transmission system, in which one or more first light sources for Raman amplification that amplify signal light transmitting in an optical transmission line and one or more second light sources for Raman amplification that are disposed at the positions adjoining the one or more first light sources for Raman amplification via the optical transmission line are provided. The optical amplification method provides the steps of, amplifying the signal light by the one or more first and second light sources for Raman amplification, transmitting the signal light in a deteriorated state of the characteristic of the signal light by that a failure occurred at one of the pumping light sources in the one or more first and second light sources for Raman amplification, detecting the deterioration state of the characteristic of the signal light by one of the second light sources for Raman amplification, and recovering the deteriorated state of the characteristic of the signal light to a normal state before deteriorated by emitting spare pumping light from a spare pumping

light source disposed in one of the second light sources for Raman amplification.

According to a twelfth aspect of the present invention, in the eleventh aspect, in case that a failure occurred at one of the pumping light sources, the spare pumping light is emitted from the spare pumping light source so that the output level of the signal light becomes the same output level before the failure occurred.

According to a thirteenth aspect of the present invention, in the eleventh aspect, in case that a failure occurred at one of the pumping light sources, the spare pumping light is emitted from the spare pumping light source so that the gain wavelength characteristic of the signal light becomes the same gain wavelength characteristic before the failure occurred.

According to a fourteenth aspect of the present invention, in the eleventh aspect, plural pumping light sources emitting plural pumping light of plural wavelengths are used as the pumping light source, and plural spare pumping light sources emitting plural spare pumping light of plural wavelengths corresponding to the plural pumping light sources are used as the spare pumping light source.

According to a fifteenth aspect of the present invention, in the eleventh aspect, outputs from the pumping light source and the spare pumping light source are controlled by respective control circuits in the one or more first and second light sources for Raman amplification.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the present invention will become more apparent from the consideration of the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram showing a structure of an optical transmission system at a first embodiment of the present invention;

Fig. 2 is output level diagrams of transmitting signal light in various optical transmission systems;

Fig. 3 is diagrams showing signal light output wavelength characteristics in each span between the light sources for Raman amplification in the various optical transmission systems;

Fig. 4 is a graph showing the relation between the failure rate of the optical transmission system and the interval between the light sources for Raman amplification having the spare pumping light sources for redundancy at the first embodiment of the present invention;

Fig. 5 is a block diagram showing a structure of an optical transmission system at a second embodiment of the present invention;

Fig. 6 is a block diagram showing a structure of a light source for Raman amplification using in an optical transmission system at a third embodiment of the present invention; and

Fig. 7 is a block diagram showing a structure of a light source for Raman amplification using in an optical transmission system at a fourth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, embodiments of the present invention are explained in detail. First, a first embodiment of the present invention is explained. Fig. 1 is a block diagram showing a structure of an optical transmission system at the first embodiment of the present invention. At the first embodiment of the present invention, two pumping light sources whose wavelengths are different from each other are used.

As shown in Fig. 1, a light source for Raman amplification 1_1

consists of a pumping light source 3 for emitting pumping light having wavelength $\lambda 1$, a pumping light source 4 for emitting pumping light having wavelength $\lambda 2$, an optical multiplexer 7 that multiplexes the emitted pumping light having wavelengths of $\lambda 1$and $\lambda 2$, an optical multiplexer 8 that inputs the multiplexed pumping light to an optical transmission line 2, a control circuit 5 for controlling the pumping light sources 3 and 4, and an optical isolator 6.

In this, each of the light sources for Raman amplification 1_2 to 1_{n-1} has the same structure as the light source for Raman amplification 1_1 has. Each of these light sources for Raman amplification 1_1 to 1_{n-1} does not have spare pumping light sources for redundancy. In this "n" is an integer being two or more. However, an "n"th light source for Raman amplification 1_n has spare pumping light sources 11 and 12 for redundancy. The spare pumping light source 11 is provided for redundancy to a pumping light source 9 and the spare pumping light source 12 is provided for redundancy to a pumping light source 10. And an optical coupler 17 couples the pumping light from the pumping light source 9 and the spare pumping light source 11. And an optical coupler 18 couples the pumping light from the pumping light source 10 and the spare pumping light source 12. As the optical couplers 17 and 18, polarized wave couplers are used.

At the light source for Raman amplification 1_n, the pumping light source 9 emits the pumping light of the same wavelength as the pumping light source 3 emits, and the pumping light source 10 emits the pumping light of the same wavelength as the pumping light source 4 emits. And also the spare pumping light source 11 emits the pumping light of the same wavelength as the pumping light source 3 emits, and the spare pumping light source 12 emits the pumping light of the same wavelength as the pumping light source 4 emits.

And at the light source for Raman amplification 1_n, the pumping light sources 9 and 10, and the spare pumping light sources 11 and 12 are controlled by a control circuit 13. And feedback is applied to these pumping light sources 9 and 10 and the spare pumping light sources 11 and 12 corresponding to the characteristics of signal light detected by a monitor (not shown) disposed at the optical transmission line 2. The spare pumping light sources 11 and 12 do not work during the normal operation of the pumping light sources and the period in which any failure is not detected in the signal light. However, when the deterioration of the signal light was detected, caused by generating an abnormal state such as lowering the output power in any of the pumping light sources, the spare pumping light sources 11 and/or 12 is worked by the control circuit 13.

And at the light source for Raman amplification 1_n, an optical multiplexer 15 multiplexes the pumping light outputted from the optical couplers 17 and 18, and an optical multiplexer 16 inputs the pumping light multiplexed at the optical multiplexers 15 to the optical transmission line 2. And also an optical isolator 14 is provided in the light source for Raman amplification 1_n.

Next, an operation at the first embodiment of the present invention is explained. For example, in case that a failure occurred at the pumping light source 4 in the first light source for Raman amplification 1_1, signal light is transmitted from the first light source for Raman amplification 1_1 onward in a state that the signal light output level and its wavelength characteristic are deteriorated. However, by making the spare pumping light source 12 in the “n” th light source for Raman amplification 1_n work, the deterioration caused by the pumping light source 4 is compensated, and the normal signal light output level and the normal wavelength characteristic can be recovered.

Referring to Figs. 2 and 3, this operation is explained in more detail. Fig. 2 is output level diagrams of transmitting signal light in various optical transmission systems. In Fig. 2, a continuous line shows an actual output level and a dotted line shows a normal output level, and plural light sources for Raman amplification 1 to n+1 are shown. Fig. 3 is diagrams showing signal light output wavelength characteristics in each span between the light sources for Raman amplification 1 to n+1 in various optical transmission systems. In Fig. 3, a horizontal line shows a normal signal light output wavelength characteristic and a slanted line shows a changed signal light output wavelength characteristic.

In Figs. 2 and 3, (a) shows a case that the pumping light sources in all the light sources for Raman amplification in an optical transmission system are working in a designated normal output level. And (b) shows the optical transmission system at the present invention in which spare pumping light sources are disposed in the "n"th light source for Raman amplification, (c) shows an optical transmission system, in which spare pumping light sources are not provided. And (d) shows an optical transmission system, in which spare pumping light sources are provided in all the light sources for Raman amplification.

And the (b), (c), and (d) show cases that a failure occurred in a pumping light source in the second light source for Raman amplification being the second repeater.

At the (b) of the present invention, a case, in which a pumping light source of wavelength $\lambda 2$ in the second light source for Raman amplification had a failure, is explained. In this case, signal light is transmitted from the second light source for Raman amplification onward in a state that the signal light output level and its wavelength characteristic are deteriorated. However, by making a

spare pumping light source of the same wavelength $\lambda 2$ in the "n"th light source for Raman amplification work, the deterioration caused by the pumping light source in the second light source for Raman amplification is compensated, and the normal signal light output level and the normal wavelength characteristic can be recovered.

At the (c), since the optical transmission system does not provide any spare pumping light sources, as shown in Figs. 2 (c) and 3 (c), from the second light source for Raman amplification onward, the signal light output level and its wavelength characteristic remain in the deteriorated levels.

At the (d), since the spare pumping light sources are provided in the second light source for Raman amplification in which a failure occurred, as shown in Figs. 2 (d) and 3 (d), the signal light output level and its wavelength characteristic are not changed in all the light sources for Raman amplification.

When the cases (b) and (d) are compared, although the signal light output level and the wavelength characteristic, which are obtained finally, are the same, the necessary number of the spare pumping light sources is different. That is, the number of the spare pumping light sources at the present invention shown in the case (b) can be 1/n of that of the case (d) at the conventional technology. As mentioned above, the present invention is especially effective at the optical transmission system, in which the light sources for Raman amplification combining plural pumping wavelengths are used for realizing particularly flat gain wavelength characteristics.

In this, at the present invention, a case, in which two wavelengths are used for the pumping light sources, is explained. However, the number of the wavelengths is not limited to two, and three or more wavelengths can be used, and the deterioration occurred in the signal light can be recovered to a normal state, by the operation

like mentioned above.

At an optical transmission system not providing any spare pumping light source, when one or more pumping light sources had failures, it is said that the optical transmission system had a failure.

Next, equations for calculating a failure rate at the optical transmission system of the present invention are explained.

For the calculation of the failure rate, an optical transmission system composed of total N light sources for Raman amplification, in which spare pumping light sources for redundancy are provided in the light sources for Raman amplification every "n" repeats, is considered. And the failure rate of a pumping light source is defined as F1r, and the failure rate of a spare pumping light source for redundancy is defined as F2r. In this, N is an integer being equal to or larger than "n".

In case that the spare pumping light sources are provided every "n"th light source for Raman amplification, the failure rate of the total light sources for Raman amplification is the sum of probability "a" and probability "b". The probability "a" is the probability that pumping light sources in two or more light sources for Raman amplification in the "n" light sources for Raman amplification have failures. The probability "b" is the probability that a pumping light source in one light source for Raman amplification in the "n" light sources for Raman amplification has a failure, and also a spare pumping light source has a failure. The probability "a" is shown in the following equation (1) and the probability "b" is shown in the following equation (2).

$$a = nC2 \times F1r^{2} + nC3 \times F1r^{3} + \cdots + nCn-1 \times F1r^{(n-1)} + nCn \times F1r^{n} \quad \ldots (1)$$

$$b = nC1 \times F1r \times F2r \ldots (2)$$

In this, nCx shows the number of combinations that extract x pieces from n pieces showing by the following equation, and the order of the extraction is free.

$$nCx = n!/x!(n-x)!$$

And a value being the sum of the probability (a) and (b) multiplied by N/n becomes the failure rate of the optical transmission system in the case that the spare pumping light sources are provided every "n" th repeater (light source for Raman amplification) at the optical transmission system composed of total N repeaters (light sources for Raman amplification). That is, the failure rate Fs of the optical transmission system is shown in the following equality (3).

$$Fs = N/n \times (a + b) \ldots (3)$$

Fig. 4 is a graph showing the relation between the failure rate of the optical transmission system and the interval between the light sources for Raman amplification having the spare pumping light sources for redundancy at the first embodiment of the present invention. As shown in Fig. 4, the necessary interval between the light sources for Raman amplification having the spare pumping light sources for redundancy can be decided by the permissible failure rate of the optical transmission system.

Next, a second embodiment of the present invention is explained. Fig. 5 is a block diagram showing a structure of an optical transmission system at the second embodiment of the present invention. At the second embodiment of the present invention, the

structures of the light sources for Raman amplification 1_1 to 1_{n-1} (not shown) are the same ones at the first embodiment. Further, the structure of the light source for Raman amplification $1_{n'}$ is equal to that of the light source for Raman amplification 1_1 and is different from that of the light source for Raman amplification 1_n at the first embodiment. That is, at the second embodiment, a light source for Raman amplification 19 specialized only for redundancy is provided additionally. As shown in Fig. 5, the light source for Raman amplification 19 consists of spare pumping light sources 20 and 21 for redundancy, an optical multiplexer 22 that multiplexes the pumping light emitted from the spare pumping light sources 20 and 21, an optical multiplexer 23 that inputs the multiplexed pumping light to an optical transmission line 2, a control circuit 24 for controlling the spare pumping light sources 20 and 21, and an optical isolator 25.

At the second embodiment of the present invention, the same effect at the first embodiment can be obtained. And at the second embodiment of the present invention, two wavelengths are used for the pumping light sources. However, the number of the wavelengths is not limited to two and three or more wavelengths can be used.

Next, a third embodiment of the present invention is explained. Fig. 6 is a block diagram showing a structure of a light source for Raman amplification using in an optical transmission system at the third embodiment of the present invention. At the third embodiment of the present invention, a light source for Raman amplification applying to upstream and downstream optical transmission lines is explained.

In Fig. 6, a light source for Raman amplification 28 being common for an upstream optical transmission line 26 and a downstream optical transmission line 27 is provided at the third

embodiment of the present invention.

As shown in Fig. 6, the light source for Raman amplification 28 having redundancy provides a pumping light source 29 for emitting pumping light having wavelength λ 1, a spare pumping light source 30 for emitting pumping light having wavelength λ 1, a pumping light source 31 for emitting pumping light having wavelength λ 2, a spare pumping light source 32 for emitting pumping light having wavelength λ 2, an optical coupler 33 that couples the pumping light λ 1 emitted from the pumping light source 29 and the spare pumping light source 30, an optical coupler 34 that couples the pumping light λ 2 emitted from the pumping light source 31 and the spare pumping light source 32, an optical multiplexer 35 that multiplexes the pumping light λ 1 and λ 2 and splits the mulitiplexed pumping light. And the split pumping light is inputted to the upstream optical transmission lines 26 and 27 respectively via respective optical multiplexers. In Fig. 6, a control circuit and optical isolators are also shown. By using the light source for Raman amplification 28 at the "n"th position in the upstream and downstream optical transmission lines, the same effect at the first embodiment can be obtained at the third embodiment of the present invention. In this, at the first to "n−1"th positions, a light source for Raman amplification, which the spare pumping light sources 30 and 31 are not provided in the light source for Raman amplification 28, are used.

Next, a fourth embodiment of the present invention is explained. Fig. 7 is a block diagram showing a structure of a light source for Raman amplification using in an optical transmission system at the fourth embodiment of the present invention. At the fourth embodiment of the present invention, a light source for Raman amplification applying to upstream and downstream optical transmission lines is explained as the same as at the third

embodiment of the present invention.

In Fig. 7, a light source for Raman amplification 36 being common for an upstream optical transmission line 26 and a downstream optical transmission line 27 is provided at the fourth embodiment of the present invention.

As shown in Fig. 7, the light source for Raman amplification 36 having redundancy provides a pumping light source 37 for emitting pumping light having wavelength $\lambda 1$, a pumping light source 38 for emitting pumping light having wavelength $\lambda 2$, a spare pumping light source 39 for emitting pumping light having wavelength $\lambda 1$, a spare pumping light source 40 for emitting pumping light having wavelength $\lambda 2$, an optical multiplexer 41 that multiplexes the pumping light $\lambda 1$ and $\lambda 2$ emitted from the pumping light source 37 and 38, an optical multiplexer 42 that multiplexes the pumping light $\lambda 1$ and $\lambda 2$ emitted from the spare pumping light sources 39 and 40, an optical multiplexer 43 that multiplexes the pumping light from the optical multiplexers 41 and 42 and splits the multiplexed pumping light. And the split pumping light is inputted to the upstream optical transmission line 26 and the downstream optical transmission line 27 respectively via respective optical multiplexers. In Fig. 7, a control circuit and optical isolators are also shown. By using the light source for Raman amplification 36 at the "n"th position in the upstream and downstream optical transmission lines, the same effect at the first embodiment can be obtained at the fourth embodiment of the present invention. In this, at the first to "n − 1"th positions, a light source for Raman amplification, which the spare pumping light sources 39 and 40 are not provided in the light source for Raman amplification 36, are used.

As mentioned above, according to the optical transmission system at the embodiments of the present invention, a redundant system (spare pumping light sources) is not provided in each of the

light sources for Raman amplification, but one redundant system is provided in one of the plural light sources for Raman amplification. Therefore, the number of components in the optical transmission system can be decreased, and also the cost manufacturing the optical transmission system can be decreased. Moreover, by the structure mentioned above, even when a failure occurs in a pumping light source, the signal light can be kept in a desirable output level and a desirable wavelength characteristic.

While the present invention has been described with reference to the particular illustrative embodiments, it is not to be restricted by those embodiments but only by the appended claims. It is to be appreciated that those skilled in the art can change or modify the embodiments without departing from the scope and spirit of the present invention.